IMPACT OF INTER-RELAY COOPERATION ON THE PERFORMANCE OF FSO SYSTEMS USING EFFICIENT RELAY

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Abstract

In this paper we study about the impact of inter-relay co-operation on the performance of the most efficient relay(compress and forward relay)under the comparison of two relays, [1] Compress and forward relay [2] Amplify and forward relay in Free Space Optical (FSO) communication. In this context, all-optical solutions or solutions that involve optical-to-electrical conversion were envisaged with either all-active or selective relaying schemes that can be implemented in the absence and presence of channel state information (CSI), respectively. The idea of inter-relay cooperation (IRC) was introduced very recently where the relay-relay links are activated for further boosting the system performance .The main layout of the system consists of a source which may be of a light emitting diode in between comes the n number of relays and at the end, destination which may be of a photovoltaic cell. Here in the inter relay cooperation each relays communicate with each other and also give acknowledgement so there is lesser probability of data loss. The relay used can be either in a parallel connection or in a series connection. Here a parallel inter relay cooperation is being used. We evaluate the outage probability of compress and forward relay and amplify and forward relay individually. The power margin which is a major issue in a wireless communication is considered as the main factor, we compare both the relays of which would consumes a low power margin during an optical transmission of data which gives a clear solution of which relay must be implemented in the FSO system.

Key Words: *Free Space Optics, Inter relay co-operation, Compress and forward relay, Amplify and forward relay, Outage Probability, Power margin*

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1. INTRODUCTION

Optical communication has been used throughout history to carry useful information. Free Space Optics technology aims at using light to transmit data from source to destination. The light can propagate through Free Space which can denote Air, Outer Space, Vacuum, or other similar media. In order to achieve communication over atmospheric FSO links, FSO employs a low-powered laser and a sensitive photo detector as the transmitter and receiver respectively. Hence the most basic point-to-point communication link is constructed. FSO communication from a source “S” to a destination “D” can be feasible in a reversed way too, thus creating a duplex link. Hence transceivers need to be implemented on both sides while having a clear LoS: Line of Sight. Moreover, FSO communication can use a Multi-path architecture, which employs more than one sender and more than one receiver. These transceivers can be implemented on buildings’ rooftops or windows, towers, poles, space stations. Inter relay co-operation in FSO using any number of relays and activating relay-relay links. We propose the system using two different relays in FSO medium namely Amplify and forward relay & Compression and forward relay.

1.1 Inter-Relay Cooperation (IRC):

The idea of inter-relay cooperation (IRC) was introduced very recently where the relay-relay links are activated for further boosting the system performance. This inter-relay cooperation can be realized either in unidirectional or in bidirectional manners resulting in two variants of this strategy; namely, IRC1 and IRC2 and also variation from NIRC (No inter relay cooperation).

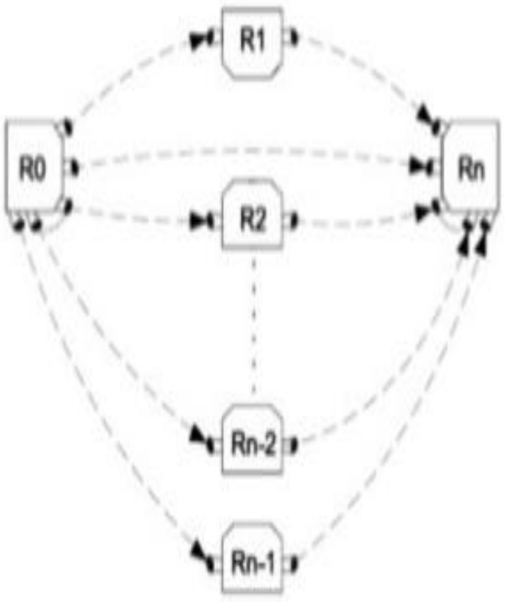

Fig -1: NIRC System

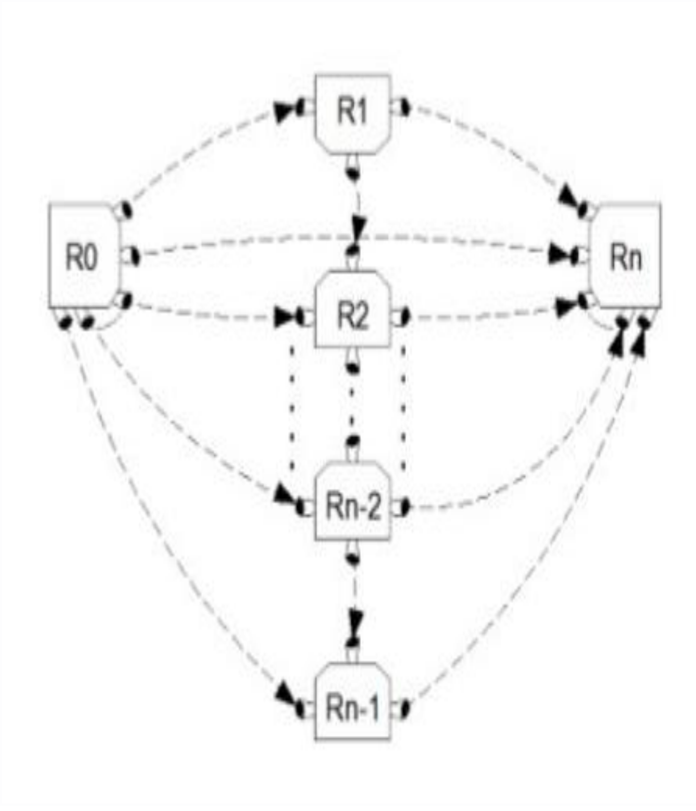

Fig -2: IRC1 Strategy

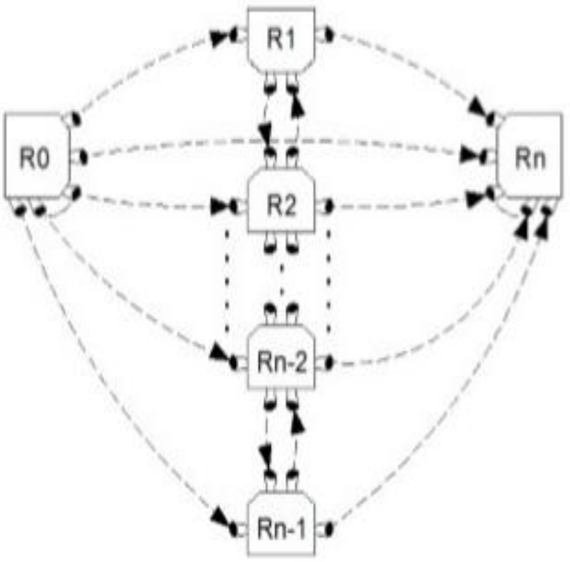

Fig -3:IRC2 Strategy

2. FSO CHANNEL MODEL

2.1 Gamma-Gamma Model and Basic Parameters

Scintillation affects the performance of the wireless optical communication systems for the terrestrial links because it mainly induces fading of the signal arriving at the receiver with random intensity. Hence, in order to assess the optical signal arriving at the receiver it is important to study the appropriate statistical distribution which describes the fading statistics. Many statistical models have been proposed for the simulation of these fading statistics caused by the atmospheric turbulence effect. Some of them have been arising from experimental results, while, others, from theoretical studies. The Gamma - Gamma distribution has become the dominant fading channel model for FSO links due to its excellent agreement with measurement data for a wide range of turbulence conditions. In this work, we adopt the widely accepted gamma-gamma turbulence-induced fading channel model where the probability density function (pdf) of the irradiance (I > 0) is given by: “() = 2() + 2 Γ()Γ() + 2 −1−(2√)” [1.1] With: - Γ(.): Gamma function - Kc(.): modified Bessel function of the second kind of order c. - The parameters and are set as: “() = [exp(0.49 2() (1 + 1.11 12 5 ()) 7 6) − 1] −1” “() = [(0.51 2() (1 + 0.69 12 5 ()) 5 6) − 1] −1 “ Parameters and vary with Raytov

Variance: 2() with the scintillation level being weighed using the variance of the beam amplitude or irradiance given by: “ 2() = 1.23 27/611/6” .As seen in the above form 2() varies according to the link 8 distance between node”i” and node “j”. Thus parameters and will vary according to the same link distance leading us to conclude that fading variance is distance dependent in FSO systems. k represents the wave number and 2 denotes the refractive index structure parameter representing the strength of the fluctuations in the refractive index. As seen in scintillation effects vary with link distance. The parameters of the link between nodes “i” and “j” can be written as: “, ≜ (,); , ≜ (,)” where , represents the length of link Ri-Rj or ,. Since the parameters and vary with the link distance, and since the pdf of the irradiance is strictly linked to these parameters then f(I) will also vary with link distances as seen in on function) of irradiance following the gamma-gamma model, hence the outage probability will vary with different link distances.

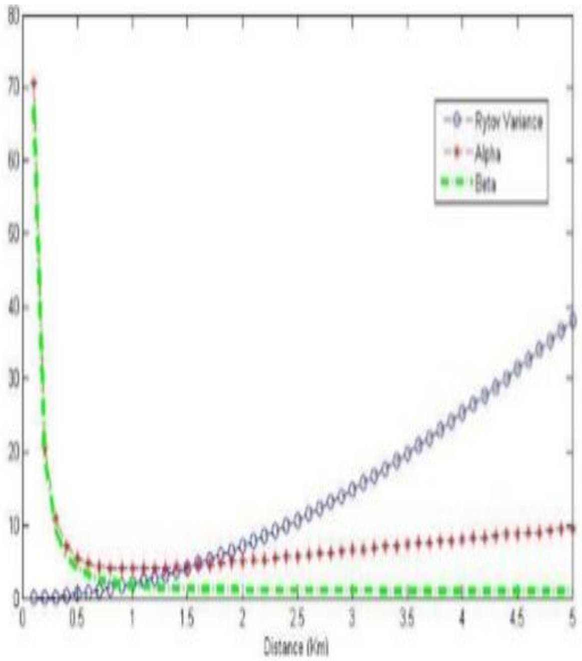

Fig -4: Scintillation Parameters Variation with Distance

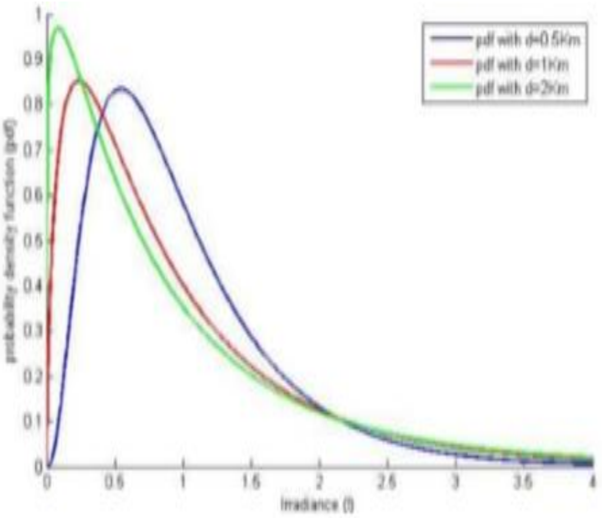

Fig -5: Gamma-Gamma Probability Density Functions

2.2 Cooperation strategy

Consider a relay-assisted FSO communication system where N relays are assumed to be present in the vicinity of a source node S and a destination node D. The relay nodes correspond to independent communication entities that are initially deployed for ensuring wireless optical connectivity between different locations. In case these nodes have no information to communicate, they can serve as relays for assisting S in its communication with D. This constitutes a major advantage of cooperative systems where no additional infrastructure needs to be deployed. In what follows, the relays will be denoted by R1, . . . ,RN . For simplicity of notation, S and D will be denoted by R0 and RN+1, respectively. We will analyze and compare the three following cooperation strategies: the No Inter-Relay-Cooperation scheme (NIRC), One-way IRC scheme (IRC1), and Two-way IRC scheme (IRC2). It is worth noting that all of these schemes can be implemented in the absence of CSI at the destination and the relays that renders them suitable for simple non coherent communications based on Intensity-Modulation and Direct-Detection (IM/DD).

$$\alpha_{i,j} = \left[\exp\left(0.49\sigma^2_{R,i,j}/(1+1.11\sigma^{12/5}_{R,i,j})^{7/6}\right) - 1\right]^{-1}$$
$$\beta_{i,j} = \left[\exp\left(0.51\sigma^2_{R,i,j}/(1+0.69\sigma^{12/5}_{R,i,j})^{5/6}\right) - 1\right]^{-1}$$

The considered cooperation strategies are based on the DF relaying scheme. In this context, the signal is first decoded at each relay followed by a re-encoding/retransmission phase. The first step involves optical-to-electrical conversion while the second step involves electrical-to-optical conversion.

$$\gamma_{i,j} = \frac{\eta^2 I^2_{i,j}}{N^2_{\text{link}} N_0}$$

1) NIRC: NIRC corresponds to the conventional two-phase all-active parallel-relaying scheme often considered in the literature. For NIRC, S first transmits the information message to D and the relays and, at a second time, the relays retransmit this message to D.

2) IRC: For the IRC schemes, after the first communication phase, the relays inter-cooperate with each other to enhance The transmission procedure is as follows. For IRC1, the signal is first transmitted from S to all relays (and D) in one time slot. The relays then perform the following operation in a sequential manner for n = 1, . . . , N: if Rn successfully decodes at least one of the signals it received along the S-Rn link or the Rn−1-Rn link (if any), then Rn retransmits this message to Rn+1 (if any); otherwise, Rn remains idle. The communications along the R1-R2, . . . ,RN−1-RN links occur sequentially over N − 1 time slots. Finally, the relays that have successfully decoded the message retransmit this message to D in the last time slot. For IRC2, after triggering the communications over the Rn-Rn+1 links, the relays perform the following operation in a sequential manner for n = N, . . . , 1: if Rn has successfully decoded the message in any of the previous slots, then Rn sends the information message to Rn−1 (if any); otherwise, this backward communication does not take place. Potential communications along the links RN - RN−1, . . . ,R2-R1 necessitate N − 1 additional slots before the final retransmission to D. the fidelity of the reconstructed symbols before the retransmission phase to D. This inter-relay cooperation can be realized either in unidirectional or in bidirectional manners resulting in two variants of this strategy; namely, IRC1 and IRC2.

(i): For IRC1, each relay retransmits the message to the next relay (if any). In other words, the decision at Rn will be based on the signals received from S and Rn−1 (if any).

(ii): For IRC2, forward-backward inter-relay cooperation is envisaged where the decision at Rn will be based on the signals received from S, Rn−1, and Rn+1 (if any). In this context, triggering communications over the existing relay-relay links is not associated with any decoding complexity where the detection procedure at each transceiver remains the same compared to non-cooperative communications. The inter-relay communication phase simply incurs an additional decoding delay that can be straightforwardly compensated for at D. Finally, it is worth noting that the considered IRC schemes are non coherent and, consequently, the extension of the existing NIRC scheme to the IRC schemes is not associated with any additional complexity for acquiring the CSI of the inter-relay links. An information carrying signal falls on each one of the different transceivers installed at a given relay. In this context, it is sufficient that at least one of these signals has a signal-to-noise ratio (SNR) that exceeds the decoding threshold to ensure the delivery of the information message to the relay. This significantly simplifies the implementation of the cooperative network where each relay simply switches to the strongest transceiver without further complications in the hardware as compared to non- cooperative systems. This also simplifies the shifting from the cooperative mode (where the relay is transmitting information of S) to the non-cooperative mode (where the relay is transmitting its own information). Finally, the number of signals that fall on each relay depends on the cooperation scheme and on the index of the relay. For IRC1, one signal is available at R1 while two signals are available at each one of the relays R2, . . . ,RN. For IRC2, two signals are available at each one of the relays R1 and RN while three signals are available at each one of the remaining relays R2, . . . ,RN−1. Following from the high directivity of FSO links, the optical signal transmitted along the link Ri-Rj does not interfere with the signals transmitted along the other links.

In particular, communicating over the relay-relay links does not incur any additional interference since the signal transmitted from a relay to the previous or next relay cannot be overheard by other nodes in the network B. Channel Model: Denote by Ii, j the irradiance along the link Ri-Rj. This irradiance can be written as the product of three terms: Ii, j = I (l) i, j I (a)i, j I (p) i, j where, in this work, we adopt a channel model that takes into account the combined effects of path loss (I (l) i, j), atmospheric turbulence-induced scintillation (I (a) i, j) and misalignment-induced fading caused by pointing errors (I (p) i, j).

A. Outage Probability along the Individual Links:

The instantaneous electrical SNR along the link Ri-Rj with IM/DD is given by [20] where η is the optical-to-electrical conversion ratio and N0 is the variance of the additive white Gaussian noise (AWGN). In, Nlink stands for the total number of links in the FSO network. The normalization by Nlink ensures that the cooperative system transmits the same power as point-to-point non-cooperative systems. Given that the considered cooperation schemes can be implemented in the absence of CSI, then this transmit power will be evenly distributed among all available links; in other words, each FSO link will be allocated a fraction Nlink of the total available transmit power. For NIRC, Nlink = 2N + 1 counting for the N S-R links, N R-D links, and the direct S-D link. For IRC1, Nlink = 3N taking into consideration the additional N − 1 inter-relay links. Finally, for IRC2, Nlink = 4N − 1 since the N − 1 inter-relay links can be activated in both directions. It is worth noting that the potential performance gains associated with IRC result from the additional number of links used for communication. This is analogous to any other spatial diversity technique where the performance gains follow from diversifying the paths along which the signal propagates from S to D.

B. Diversity Order along the Individual Links:

Equation does not offer intuitive insights on the behavior of pi, j . Consequently, we will further proceed with an asymptotic analysis. For large SNRs, the outage probability is dominated by the behavior of the pdf near the origin where can be approximated by f Ii, j (I) ≈ ai, j I ζi, j−1 where ζi, j = min{βi, j, ξ2 i, j } and:

$$a_{i,j} = \frac{\xi_{i,j}^{2}(\alpha_{i,j}\beta_{i,j})^{\zeta_{i,j}}\Gamma(\alpha_{i,j}-\zeta_{i,j})}{(A_{i,j}I_{i,j}^{(l)})^{\zeta_{i,j}}\Gamma(\alpha_{i,j})\Gamma(\beta_{i,j})}b_{i,j}$$

$$p_{i,j} \approx \frac{a_{i,j}}{\zeta_{i,j}}\left(\frac{\xi_{0,N+1}^{2}+1}{A_{0,N+1}I_{0,N+1}^{(l)}\xi_{0,N+1}^{2}}\frac{\mathcal{P}_M}{N_{\text{link}}}\right)^{-\zeta_{i,j}}$$

C.IRC with N Relays

After introducing the different probability definitions and highlighting on the cases that might arise in IRC systems with N = 3, we next tackle the general case of IRC systems with N ≥ 2. The outage probability of the overall FSO system can be written as:

$$P_{\text{out}} = p_{0,N+1}\sum_{n=0}^{N}\sum_{i=1}^{\binom{N}{n}}\left[\prod_{j\in\mathfrak{I}_{n,i}} q_{0,j}\right]\left[\prod_{j'\in\overline{\mathfrak{I}}_{n,i}} p_{0,j'}\right]\times \left[\prod_{j\in\mathfrak{I}_{n,i}} p_{j,N+1}\right]P_{\mathfrak{I}_{n,i}}^{(\text{IRC})}$$

3. OUTAGE ANALYSIS

The outage probability of the overall FSO system depends on the power margin PM, on the network setup (through the channel parameters αi, j , βi, j , ξi, j , Ai, j and I (l) i, j),

and on the number of relays N. In order to offer more insights on the performance of IRC1 and IRC2, we first consider the special cases of N = 2 and N = 3

$$P_{\mathfrak{I}_{n,i}}^{(\text{IRC1})} = \prod_{k=1}^{m_{n,i}} p_{\max\{\mathcal{N}_{n,i}^{(k)}\}\to\min\{\mathcal{O}_{n,i}^{(k+1)}\}\to\cdots\to\max\{\mathcal{O}_{n,i}^{(k+1)}\}}$$

1) IRC1: In this case, given that the inter-relay cooperationis implemented only in the forward direction, then inter-relay cooperation will not benefit the first group of relays that were already in outage before the inter-relay cooperation phase (whose indices are given in O(1) n,i) where these relays will remain in outage after inter-cooperation between the relays. On the other hand, relays whose indices fall in O(k+1) n,i for k > 0can benefit from inter-relay cooperation since these relays can receive the information message from the previous cluster of relays that are not in outage; i.e .from the relays whose indices fall in N(k).

$$P^{(\mathrm{IRC2})}_{\mathcal{J}_{n,i}} = p_{\min\{\mathcal{N}^{(1)}_{n,i}\}\to\max\{\mathcal{O}^{(1)}_{n,i}\}\to\cdots\to\min\{\mathcal{O}^{(1)}_{n,i}\}} \times$$

$$\prod_{k=2}^{m_{n,i}} p_{\max\{\mathcal{N}^{(k-1)}_{n,i}\}\to\left(\min\{\mathcal{O}^{(k)}_{n,i}\}\rightleftarrows\cdots\rightleftarrows\max\{\mathcal{O}^{(k)}_{n,i}\}\right)\leftarrow\min\{\mathcal{N}^{(k)}_{n,i}\}} \times$$

$$p_{\max\{\mathcal{N}^{(m_{n,i})}_{n,i}\}\to\min\{\mathcal{O}^{(m_{n,i}+1)}_{n,i}\}\to\cdots\to\max\{\mathcal{O}^{(m_{n,i}+1)}_{n,i}\}}$$

3.1 Diversity Order and Asymptotic Analysis:

A. Diversity Order

Consider the outage probability. For large values of the SNR, given that pi, j scales asymptotically as P −ζi, j M and qi, j = 1 − pi, j ≈ 1, then the first product in (14) is approximately equal to 1, the second product scales asymptotically as P −_ j ∈In,I ζ0, j M , and the third product scales as P−_j∈In,I ζ j,N+1 M . For NIRC, P(IRC) In,I = 1 in (14) and the diversity order of the NIRC scheme can be written as:

$$\zeta^{(\mathrm{IRC1})} = \zeta_{0,N+1} + \min_{n=0,\ldots,N} \min_{i=1,\ldots,\binom{N}{n}} \{\zeta^{(0)}_{\mathcal{J}_{n,i}} + \zeta^{(\mathrm{f})}_{\mathcal{J}_{n,i}}\}$$

Comparison of the IRC Schemes with NIRC ζ = ζ0,N+1 + min I⊂{1,...,N} {ζ (0) I + ζ (1) I } (35) where ζ (0) I is defined in (28). ζ (1) I is equal to 0, ζ (f) I , and ζ (f) I + ζ (b) I for NIRC, IRC1, and IRC2, respectively, where ζ (f) I and ζ (b). Given the cumbersome expressions of the diversity order, it is of extreme importance to highlight under which network conditions will inter-relay cooperation be useful. In [23], it was proven that (27)–(28) can be written as: ζ (NIRC) = ζ0,N+1 + _N n=1 min{ζ0,n, ζn,N+1}.

$$\zeta^{(\mathrm{NIRC})} = \zeta_{0,N+1} + \sum_{n\in\mathcal{S}} \zeta_{n,N+1} + \sum_{n'\in\overline{\mathcal{S}}} \zeta_{0,n'} = \zeta_{0,N+1} + \zeta^{(0)}_{\mathcal{S}}$$

1) Case A: Assume first that there are no relays Rn for which ζ0,n = ζn,N+1. Construct the set S as follows Comparison Between IRC1 With IRC2 in Case 3 It is more convenient to tackle the problem by analyzing the diversity gain _ζ(IRC) _ ζ (IRC) − ζ (NIRC) of an IRC scheme with respect to the NIRC scheme. ζ (NIRC) = ζ0,N+1 + ζ (0) S , then _ζ(IRC) = minI⊂{1,...,N}{ζ (0) I−ζ (0)S+ ζ (1)I}. It can be easily proven that ζ (0)I − ζ (0)S = _ n∈I⊕S χn where I ⊕ S stands for the set of elements that belong to I ∪ S but not to I ∩ S and:

$$\zeta^{(\mathrm{NIRC})} = \zeta_{0,N+1} + \sum_{n\in\mathcal{S}} \zeta_{n,N+1} + \sum_{n'\in\overline{\mathcal{S}}\setminus\mathcal{S}^{(\mathrm{eq})}} \zeta_{0,n'} + \sum_{n''\in\mathcal{S}^{(\mathrm{eq})}} \zeta_{n'',N+1}$$

3. 2 Numerical Results and Discussion

The refractive index structure constant and the attenuation constant are set to C2 n = 1 × 10−14 m−2/3 and σ = 0.44 dB/km. In all scenarios, the distance between S and D is d0, N+1 = 5 km. The receiver radius, beam waist, and pointing error displacement standard deviation are assumed to be the same for all links and they will be denoted by a, ωz , and σs , respectively. In what follows, we set σs/a = 3. The values of ωz/a will be varied in the simulations where large values of this ratio indicate less pointing errors. The set of distances D is defined as: D _ { ▪ }(d0,n, dn,N+1)}N n=1 where the sign + (resp. −) indicates that the relay is above (resp. below) the line formed by joining S and D in a two dimensional plane. We will provide simulations under different network configurations reflecting the following four scenarios that might arise when comparing the IRC and NIRC schemes. Scenario 1: ζ (IRC2) = ζ (IRC1) = ζ (NIRC), scenario 2: ζ (IRC2) > ζ (IRC1) = ζ (NIRC), scenario 3: ζ (IRC2) = ζ

(IRC1) $>$ ζ(NIRC) and scenario 4: ζ (IRC2) $>$ ζ(IRC1) $>$ ζ(NIRC). An extensive simulation campaign highlighted the extremely close match between the numerical and analytical results (where the corresponding curves were barely distinguishable) thus supporting the validity of the provided derivations. performance of 3-relay and 5-relay networks for which neither IRC1 nor IRC2 is useful corresponding to scenario 1. We set $\omega z/a = 10$, $D = \{(1, 4.2), (1.5, 3.6), -(2, 3.1)\}$ for $N = 3$ and $D = \{(3, 2.4), (3.3, 2), (3.6, 1.6), -(3.7, 1.5), -(3.8, 2.2)\}$ for $N = 5$. This scenario corresponds to case 1 in subsection IV-B where $S = \{1, 2, 3\}$ for $N = 3$ and $S = \varphi$ for $N = 5$. Results show the very close match between the exact outage probabilities based on (8) and the asymptotic values based on (10) for large values of the power margin PM. Results also support the accuracy of the derived expressions for the diversity order where the analytical values based on (27) and (28) for NIRC, on (29) and (31) for IRC1 and on (31), (33) and (34) for IRC2 closely match the negative slopes of the different outage probability curves. These formulas accurately predict diversity orders of 6.4 and 10 for $N = 3$ and $N = 5$, respectively. For this scenario, NIRC is the best solution not only because it achieves the same diversity order as IRC1 and IRC2 with a reduced system complexity but also since it achieves a slightly better performance than these two IRC schemes. This results from the increase of the total number of links Nlink from NIRC to IRC1 and IRC2 implying that the transmit power will be divided among a larger number of links. we provide examples of networks with different number of relays for which scenario 2 arises. We set $\omega z/a = 25$ while D takes the following values: $\{(2.6, 2.5), (3.2, 1.8), -(2.7, 4.6)\}$ for $N = 3$, $\{(2.6, 2.5), (3.2, 1.8), -(2.7, 4.3), -(2.9, 4.7)\}$ for $N = 4$ and $\{(2.6, 2.5), (3.4, 1.6), -(2.7, 3.4), -(2.6, 3.9), -(2.6, 4.3), -(2.7, 4.6)\}$ for $N = 6$. The superiority of IRC2 over IRC1 (that achieves the same diversity order as NIRC) was predicted theoretically by case 2 in subsection IV-B since $S = \{3\}$ for $N = 3$, $S = \{3, 4\}$ for $N = 4$ and $S = \{3, 4, 5, 6\}$ for $N = 6$. For the considered simulation setup, the gain in the diversity order offered by IRC2 (with respect to either IRC1 or NIRC) is 0.86, 1.46, and 2.93 with 3, 4, and 6 relays, respectively. In all scenarios, the performance gains with respect to non-cooperative systems are huge for average-to-large values of PM. Scenario 3 is reflected with $N = 2$ and $N = 4$ for $\omega z/a = 8$ and $\omega z/a = 25$.We set $D = \{(1, 4.1), -(4.1, 1)\}$ for $N = 2$ and $D = \{(1, 4.1), (1.5, 3.5), -(3.2, 1.9), -(4, 1.8)\}$ for $N = 4$. Results highlight the enhanced diversity orders and performance levels that can be achieved by activating the inter relay links. In this scenario, IRC1 and IRC2 achieve the same diversity order where the outage probability curves are practically parallel to each other for large values of PM. This renders IRC1 the most adapted solution under this scenario. In this case, IRC2 even results in a small performance loss with respect to IRC1 since the transmit power needs to be divided among a larger number of links. In this example, for $N = 2$, the diversity order of NIRC does not increase when $\omega z/a$ increases from 8 to 25 where the diversity order remains 4.33. This shows that the performance of the NIRC network is limited mainly by atmospheric turbulence rather than pointing errors; in this case, reducing the pointing errors does not manifest in an improved diversity order. Interestingly, this is not the case with IRC where the diversity order increases from 4.64 for $\omega z/a = 8$ to 6.15 for $\omega z/a = 25$. For the IRC network, both atmospheric turbulence and pointing errors affect the performance and, hence, reducing the pointing errors results in an increase in the diversity order. This is reflected in large performance gains that range from 2.5 dB for $\omega z/a = 8$ to 6 dB for $\omega z/a = 25$ when comparing IRC1 with NIRC at an outage probability of $10-10$. For $N = 4$, ζ (NIRC) $= 7.88$ and ζ (IRC2) $= \zeta$ (IRC1) $= 8.16$ for $\omega z/a = 8$ while ζ (NIRC) $= 7.94$ and ζ (IRC2) $= \zeta$ (IRC1) $= 11.96$ for $\omega z/a = 25$. Scenario 4 is for $\omega z/a = 25$ with different number of relays. The values of D are $\{(2.7, 2.2), -(2.8, 4.6), -(3.7, 3.2)\}$ for $N = 3$, $\{(1, 4.1), (4.1, 1), -(3.9, 1.5), -(1.5, 3.9)\}$ for $N = 4$, and $\{(1, 4.1), (4.1, 1), -(3.9, 1.5), -(2.3, 2.9), -(2.9, 2.3), -(1.5, 3.9)\}$ for $N = 6$. The simulated network for $N = 3$ corresponds to the example provided in subsection IV-C where the diversity gains of IRC1 and IRC2 with respect to NIRC are provided in (49)–(50). For this network, $\chi 1 = 0.75$, $\chi 2 = 0.86$, $\chi 3 = 0.23$, $\zeta 1,2 = 1.94$, and $\zeta 2,3 = 3.76$ implying that IRC2 will achieve higher diversity order than IRC1 according to (51). In this case, the diversity order of IRC2 exceeds the diversity order of IRC1 by _ζ(IRC2) $-$ _ζ(IRC1) $= \chi 2 - \chi 3 = 0.63$. For $N = 4$, huge gains in the diversity order can be observed where ζ (NIRC) $= 7.46$, ζ (IRC1) $= 9.34$, and ζ (IRC2) = 11.7. Similarly, ζ (NIRC) = 11.58, ζ (IRC1) = 14.13, and ζ (IRC2) = 17.7 for N = 6.

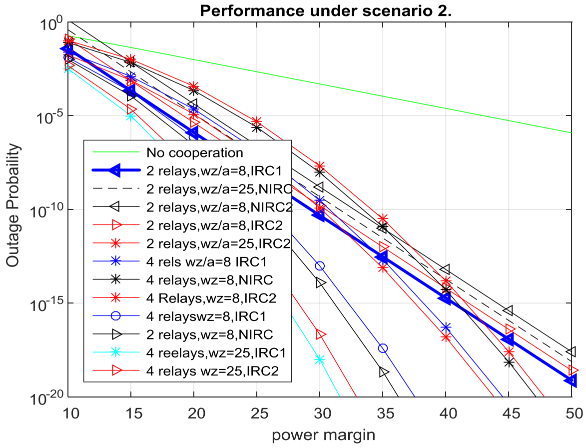

Fig -6: Comparison of 3 relays and 5 relays network

4. CONCLUSIONS

In the context of FSO collaborative systems, communicating over the existing relay-relay links constitutes an additional degree of freedom that can be exploited to enhance the achievable diversity orders and performance levels. Special consideration needs to be paid to the engineering of such systems since inter-relay cooperation is not useful in all circumstances. Even in the scenarios where inter-relay cooperation is capable of increasing the diversity order, the achievable gains are highly dependent on the particular network topology. In some cases the minor gains in the diversity order do not justify the upsurge in the system complexity that results from implementing the IRC techniques; in other cases, significant gains can be reached stressing on the huge potential of IRC techniques.

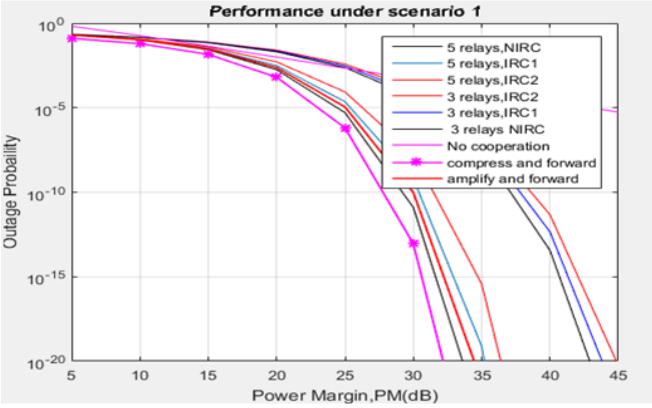

Fig -7: Comparison of compress and forward relay
to amplify and forward relay

From the above graph, it is observed tat the power margin of Compress and forward relay is less than that of the Amplify and forward relay. Further it is concluded that the Compress and forward relay is the most efficient relay in the comparison. Therefore using the Compress and forward relay, the communication is successfully performed in FSO system.

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